Cyber Safety & Security for Reduced Crew Operations

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This work was performed under NASA contract NNC11BA15B.

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Overview

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Reduced Crew Operations (RCO) would be more than "Flight Management on steroids"

An RCO system will

- **have to be *highly invasive into most, or all, existing safety-critical aircraft systems***
- **require a *highly-reliable data communication* system that offers very low latency and jitter, as well as high data integrity and authentication**

Levels of autonomy and authority (CRM)

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- **Cockpit Crew (CC) vs Ground Crew (GC)**
  - CC is flying, GC is just standby redundancy
  - CC is flying, GC is active second pilot
  - GC is flying, CC is active second pilot (PNF)
  - GC is flying, CC is just standby

creates

  - GC is flying, CC is an adversary or is suicidal?!
  - CC is flying, GC is an adversary (spoofed)?!?!

mutually exclusive

Q's and Preliminary A's for Degree of Authority

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- **Can RCO be used to assist (partially) able-bodied airborne crew?**
- **… totally incapacitated airborne crew?**
  - **In the UK, there were 32 in 2009 and 36 in 2004 (~1 per 10 days)**
- **Can a GC via RCO be used to override a "rogue" cockpit crew?**

Onboard Safety-Critical Systems

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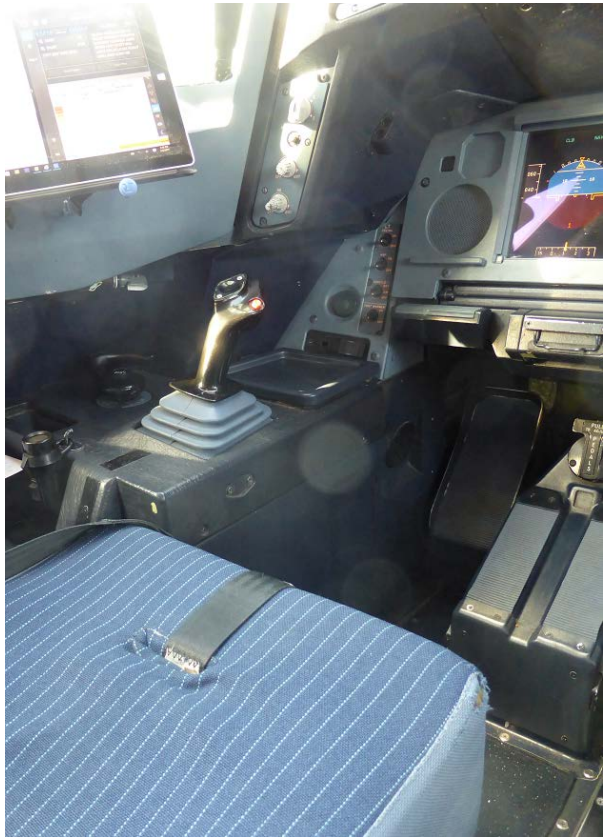
- **Traditional 3 layers of aircraft control automation**

more authority, but more stringent latency

- Flight Management System
- Auto Pilot
- Flight Control

controls

controls



RCO System Architecture

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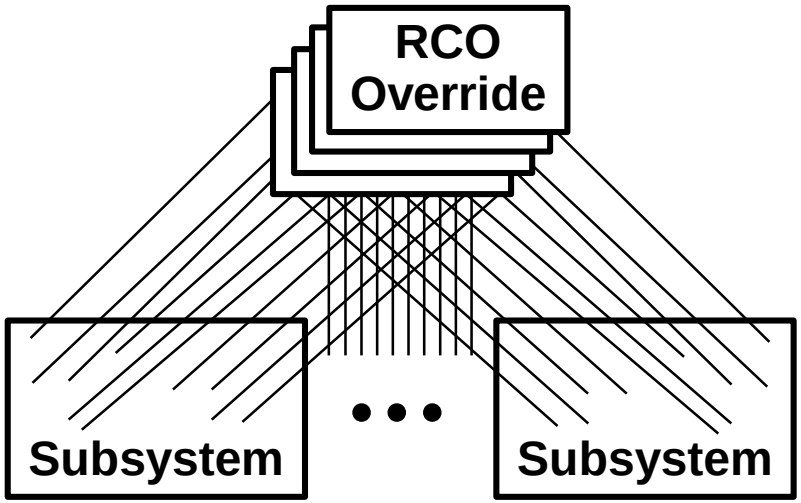
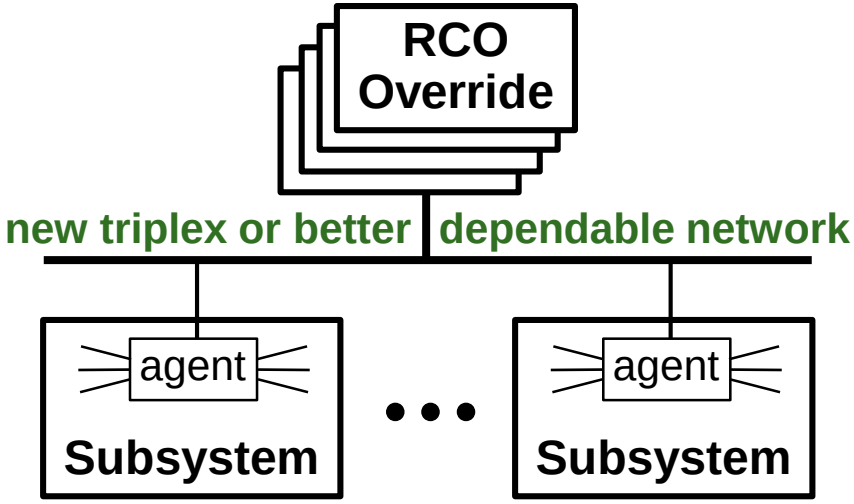
Centralized “Porcupine”



Remote Agents



RCO Fault Tolerance

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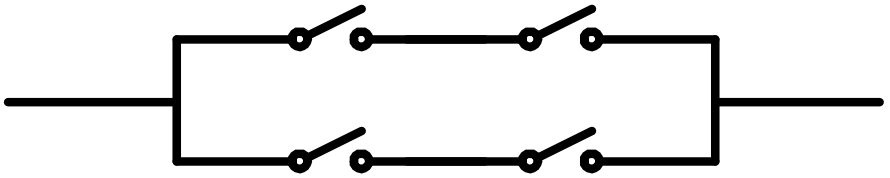
- An RCO system would need to be Byzantine fault tolerant
- Some/most actuators would have to be quad redundant



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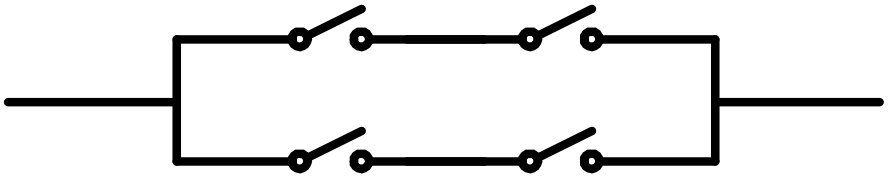

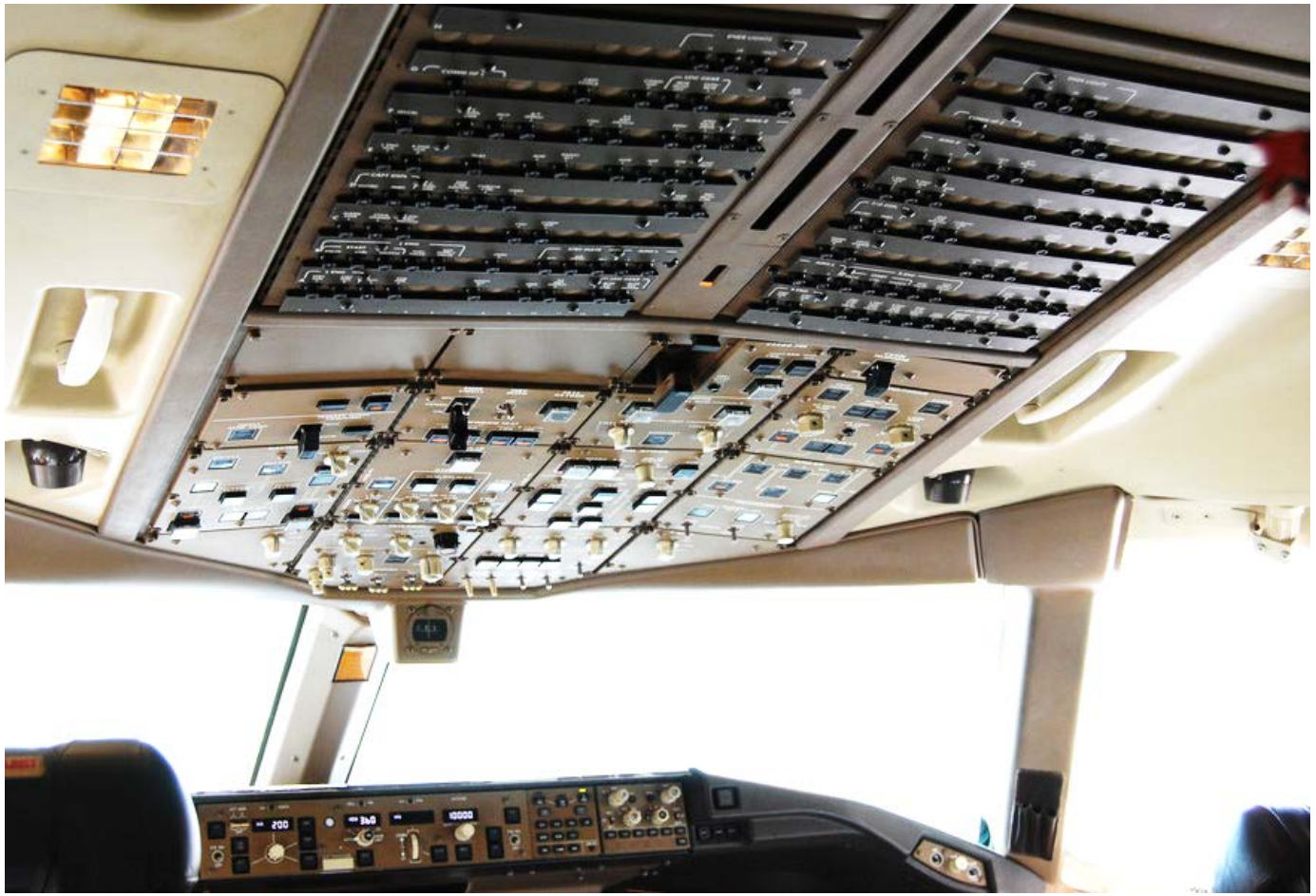

Don’t Re-invent the Wheel

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- **Not much R&D done for aircraft RCO safety/security**
- **Looked at R&D done in adjacent fields**
  - **UASs (drones)**
  - **Autonomous ground vehicles (shared control)**
    - “***Right now, there’s no good answer***, which is why we’re kind of avoiding that space”

-- Dr. Ken Washington
Ford VP

Control Hand-Back Problems

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- **Paul Schutte:**
  - "computers […] give up at the first sign of trouble"
- **Scenarios**
  - **When at the controls, time to regain situational awareness**
    - Air Canada 878: napping
    - Audi
    - Qantas Flight 32
  - **Time to get to the controls, when in cockpit**
    - Aeroflot 593: kids at the controls
  - **Time to get to the controls, when out of cockpit**
    - Delta (Chautauqua) 6132: captain stuck in the WC

Typical Abnormality Requiring Crew to Leave Cockpit

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Are There Real Communication Threats?

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- **Individuals**
  - **Officially called "phantom controllers"**
    - UK: 18 times in 1999
  - **Jim Epik's book "Phantom Controller" and petition to encrypt ATC**
- **Groups**
  - **1981 PATCO**
  - **Opposing factions in civil wars**
- **Nation-State sponsored**
- ***Yes, we have to assume there will be bad actors who are out to get us.***

Some Crypto Key-Management Issues

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- **Two aspects of key-management**
  - **Trust**
  - **Logistics**
    - Key distribution and management
      - ***Distribution needs secrecy even if these keys are used only for authentication, not secrecy!***
- **Invention to mitigate logistic issues for avionics**
  - **No secrets stored on aircraft**
  - **Simplifies the airborne side of link**
- **Issue: Whose keys?**
- **(Inter)national cryptography laws**

Cryptography Import Laws

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Country	Status	Updated
Angola	Unknown	2000
Armenia	Green/Yellow	2000
Bahrain	Yellow	2008
Belarus	Red	2008
Brunei Darussalam	Yellow/Red	2000
Cambodia	Yellow	2008
Canada	Green	2015
Czech Republic	Green/Yellow	2008
China	Yellow	2008
Egypt	Yellow	2007
Ghana	Green	2008
Hong Kong	Green/Yellow	2008
Hungary	Green/Yellow	2008
India	Green/Yellow	2008
Iran	Yellow	2008
Iraq	Red	2000
Israel	Yellow	2008
Khazakstan	Yellow	2008
Latvia	Yellow	2008
Lithuania	Yellow	2008
Malta	Yellow	2000

Country	Status	Updated
Moldova	Yellow	2008
Mongolia	Red	2000
Morocco	Yellow	2008
Myanmar (Burma)	Red	2008
Nepal	Unknown	2000
Nicaragua	Unknown	2000
North Korea	Unknown/Red	2008
Pakistan	Yellow	2008
Poland	Green/Yellow	2008
Russia	Red	2008
Rwanda	Unknown	2008
Saudi Arabia	Green	2008
Singapore	Green	2008
South Africa	Green/Yellow	2008
South Korea	Yellow	2008
Tatarstan	Unknown	2000
Tunisia	Yellow/Red	2008
Turkmenistan	Red	2000
Ukraine	Yellow	2007
Uzbekistan	Red	2000
Vietnam	Yellow	2008

- **Red**:
  Total ban
- **Yellow**:
  License required for importation
- **Green**:
  No restriction

- Taken from: en.wikipedia.org/wiki/Restrictions_on_the_import_of_cryptography

Latency Problem?

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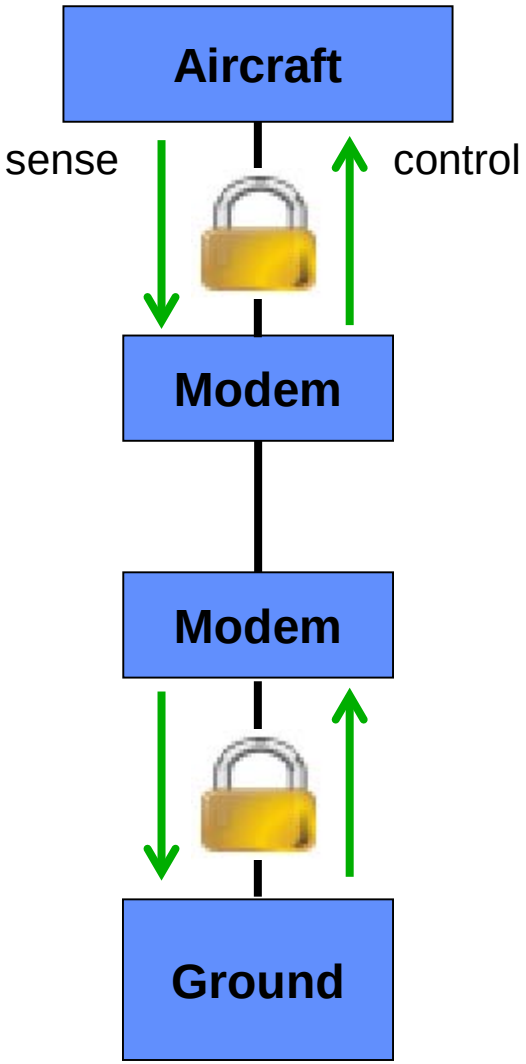

Does the sum of all these added latencies exceed the round-trip latency constraints?

Problems with existing cryptography when applied to cyber-physical systems

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- Slow startup for each key change
- Use too much data memory
- Need more communication bandwidth
- Use separate secrecy and integrity algorithms or added integrity mode
- Many new cyber-physical cryptography installations will be retrofits, which further exacerbates the above problems
- These are the reasons we created an algorithm (called BeepBeep) specifically for real-time and/or retro-fit applications.

Conclusions

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- **A high-capability RCO system:**
  - May introduce significant safety and security hazards
  - Could be a “single point of failure” for the entire aircraft
- **Technology not ready yet**
  - Research is needed into designing multi-chapter “Level A+” systems
  - Research is needed into the use cryptography for low-latency and international applications
- **RCO capability may be acceptable in the more near term for Part 135, cargo flights, and/or restricted routes and airfields**

Thank you for your attention.

Questions?

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